



The JPL Tropical Cyclone Information System: A Wealth of Data for Quickly Advancing the Physical Understanding and Forecasting of Hurricanes.

Svetla Hristova-Veleva¹, P. Peggy Li¹, Brian Knosp¹, Quoc Vu¹, F. Joseph Turk¹, William L. Poulsen¹, Ziad Haddad¹, Bjorn Lambrigtsen¹, Bryan Stiles¹, Tsae-Pyng Shen¹, Noppasin Niamsuwan¹, Simone Tanelli¹, Ousmane Sy¹, Hui Su¹, Deborah G. Vane¹, Yi Chao¹, Philip S. Callahan¹, R. Scott Dunbar¹, Michael Montgomery², Mark Boothe², Vijay Tallapragada³, Samuel Trahan³, Anthony J. Wimmers⁴, Robert Holz⁴, Jeffrey Reid⁵, Frank Marks⁶, Tomislava Vukicevic⁶, Saiprasanth Bhalachandran⁷, Hua Leighton⁸, Sundararaman Gopalakrishnan⁶, Andres Navarro⁹, Francisco J. Tapiador⁹

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⁸ – Hurricane Research Division/AOML/NOAA/University of Miami, RSMAS

⁹ – UCLM, Earth and Space Sciences Research Group

July 9th, 2021

1. Motivation:

The critical pathway to hurricane forecast improvement is to **use observations and models together to:**

- Advance the still-lacking **understanding of the governing processes**
- **Evaluate and improve models** through the use of satellite data
- **Develop advanced techniques for assimilating of satellite observations inside the hurricane core**

Despite the significant amount of satellite data today, they are still underutilized in hurricane research and operations, due to their volume and complexity (indirect and very nonlinear sensitivity to the most important underlying model variables).

To support the needs of the research and operational communities, several NASA -funded efforts resulted in the development of the **Tropical Cyclone Information System** - a hurricane-specific Data Analytic Center Framework

The TCIS components:

- **Three interactive portals:**
 - the **North Atlantic Hurricane Watch** (NAHW - <https://nahw.jpl.nasa.gov>)
 - **data portals to support field campaigns to study tropical convection**
 - They serve as a very rich information source during the planning and particularly during the analysis stages of field campaigns
 - **NASA's 2017 Convective Processes Experiment (CPEX)** (<https://cpex.jpl.nasa.gov>)
 - **NASA's 2019 CAMP2Ex** - <https://camp2ex.jpl.nasa.gov>
 - **NASA's 2021 CPEX-AW** – <https://cpex-aw.jpl.nasa.gov>
- A 12-year-long (1999–2011) **global data archive (TCDA)** of satellite observations of tropical cyclones (non-interactive).
 - a one-stop place to obtain an extensive set of multi-parameter data from multiple observing systems.
 - offers both digital data and imagery, subset to the domain and time of interest, thus greatly reducing the volume of unwanted data.
 - This makes TCDA a valuable source to quickly build statistics in support of research, forecast improvement and algorithm development

<https://tropicalcyclone.jpl.nasa.gov>

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TROPICAL CYCLONE INFORMATION SYSTEM

Welcome to the JPL Tropical Cyclone Information System

The JPL Tropical Cyclone Information System is being actively developed to help scientists improve their understanding and forecasting of hurricanes. It has two components: a set of near real-time portals that integrate model forecast with multi-parameter satellite and airborne observations from a variety of instruments and platforms, providing interactive visualization and some on-line analysis tools that work with both observations and models, and a 12-year global archive of multi-satellite hurricane observations.

Below you will find links to various portals where you can view different types of data.

- ◀ Introduction
- ◀ News
- ◀ Team
- ◀ Collaborators
- ◀ Funding
- ◀ Publications

North Atlantic Hurricane Watch (NAHW)

The North Atlantic Hurricane Watch data portal monitors hurricanes in the North Atlantic and East Pacific ocean basins. This near real-time interactive data portal was originally developed to support the multi-year Hurricane and Severe Storm Sentinel (HS3) aircraft campaign. HS3 was a five year mission with a three year airborne component (2012-2014). This portal allows users to analyze and compare observation data and model forecasts during each hurricane season (June - November) from 2012 to the present day.

- [NAHW tutorial video](#)

Convective Processes Experiment - Aerosols & Winds (CPEX-AW) & Convective Processes Experiment (CPEX)

The 2021 NASA Convective Processes Experiment - Aerosols & Winds campaign will study the dynamics and microphysics related to the Saharan Air Layer, African Easterly Waves and Jets, Tropical Easterly Jet, and deep convection in the InterTropical Convergence Zone (ITCZ).

The 2017 NASA Convective Processes Experiment (CPEX) aircraft campaign collected data that could help to answer questions about convective storm initiation, organization, and growth. This near real-time data portal was run from May to July of 2017 in support of the observational phase of CPEX. It collected data from satellite instruments and instruments flying on-board the campaign's DC-8 aircraft.

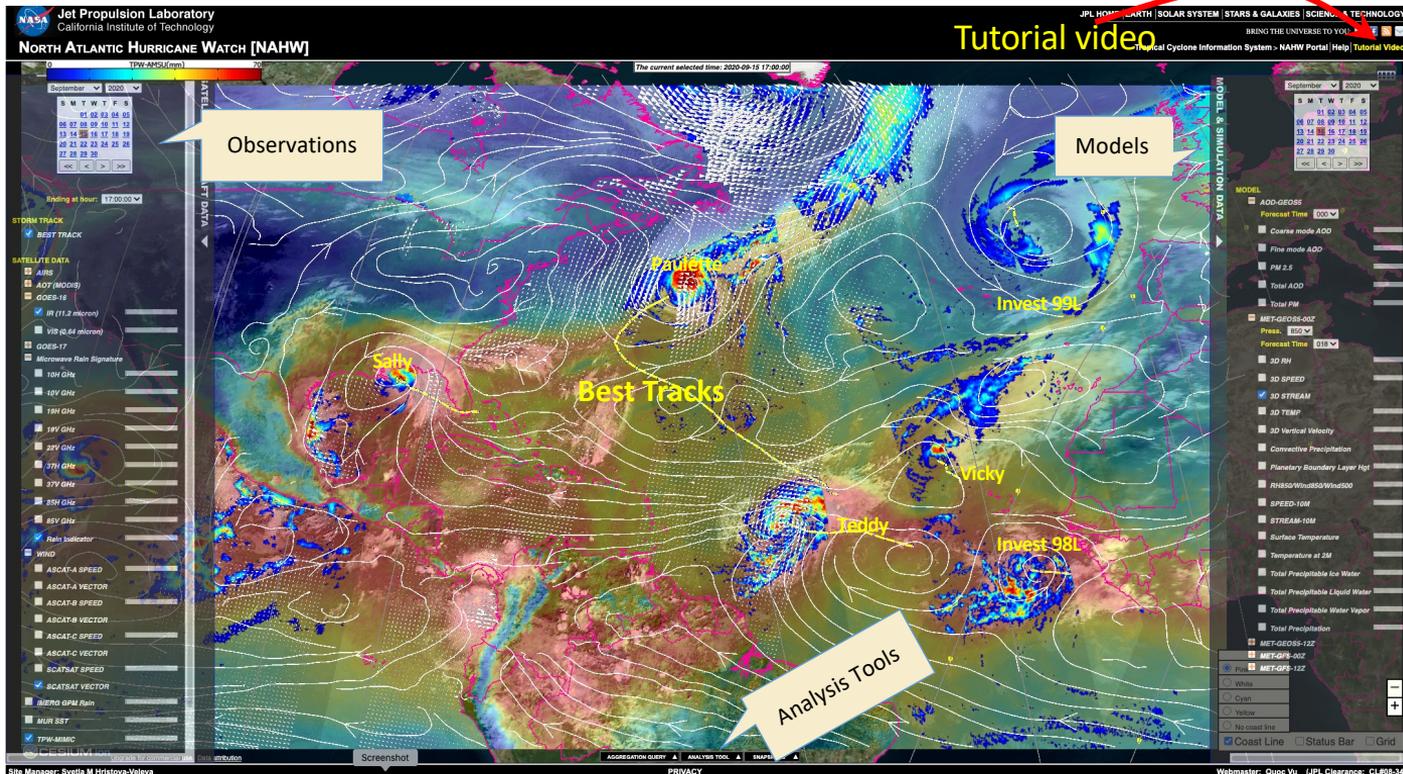
Additional information about both campaigns is available from the [CPEX website](#).

The Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP2Ex)

The Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP2Ex) is a response for the need to deconvolute the fields of tropical meteorology and aerosol science at the meso- β to cloud level. Campaign operations were based at Clark International Airport (Philippines). The aircraft field campaign took place mid August - October 6, 2019 on the NASA P3 and the SPEC Learjet 35 platforms. To allow studies of the interannual variability and to put the CAMP2Ex mission observations in the context of this variability, the CAMP2Ex portal will collect satellite and model data over an extended period, including one year after the end of the field campaign. Additional information is available from the [CAMP2Ex website](#).

Site Manager: Svetlita M Hristova-Velova Screenshots PRIVACY Webmaster: Quoc Vu (JPL Clearance: CL#08-3498)

JPL TCIS - Interactive Visualization of multiparameter observations and models



Tutorial video

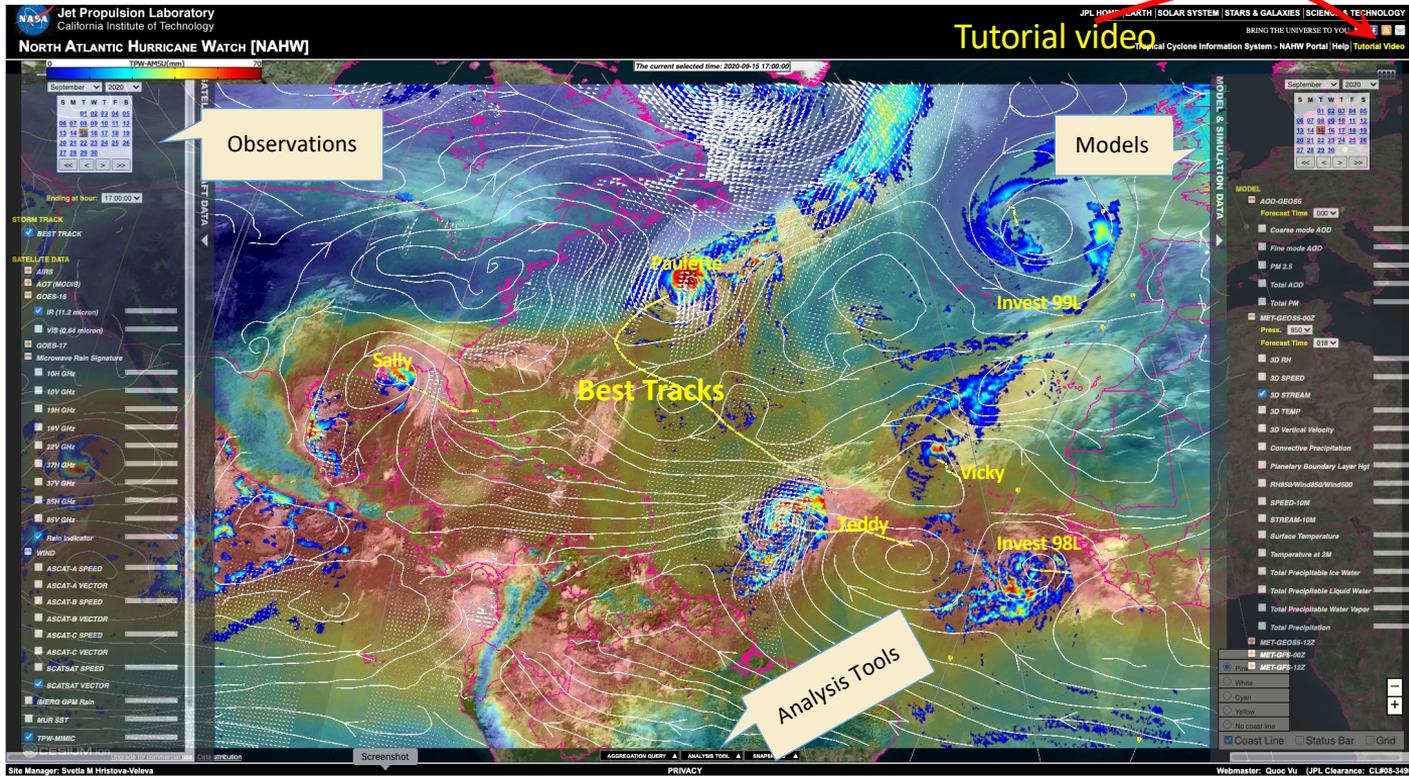
To support the needs of the research and operational communities, several NASA-funded efforts resulted in the development of the JPL Tropical Cyclone Information System – a Data Analytic Center Framework that:

- ingests and processes dozens of data streams
- combines model forecasts with satellite and airborne observations, bringing them all within a common system.

This system

- provides interactive visualization
- supports some on-line analysis tools that can be used with both observations and models.

JPL TCIS - Interactive Visualization of multiparameter observations and models



Tutorial video

To support the needs of the research and operational communities, **several NASA-funded efforts** resulted in the development of the **JPL Tropical Cyclone Information System** – a **Data Analytic Center Framework** that:

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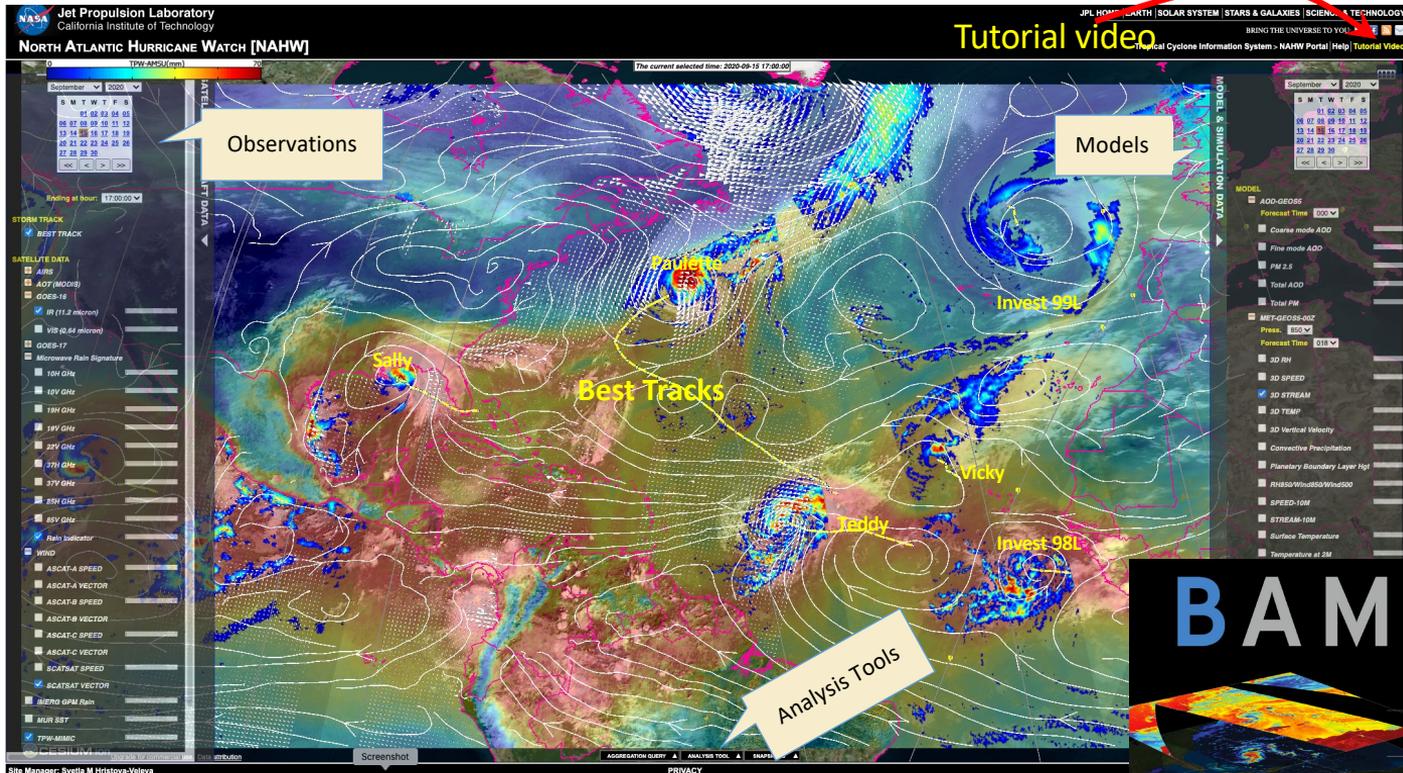
This system

- provides interactive visualization
- supports some on-line analysis tools that can be used with both observations and models.

The goal of the JPL TCIS data analytic framework is to help scientist:

1. gain intuition in the complex multi-scale interactions that lead to the evolution of tropical convection in general and hurricane processes, in particular
2. To support airborne flight campaigns: planning, in-air flight operations
3. To provide a common system for post-event exploratory analysis
4. To provide the data (satellite and model) that are included in the TCIS

JPL TCIS - Interactive Visualization of multiparameter observations and models



Observations

Models

Best Tracks

Analysis Tools

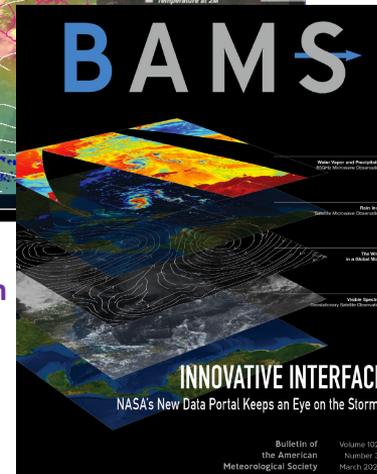
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The JPL TCIS is described in the March 2021 issue of BAMS and featured on the Cover.



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2. To support airborne flight campaigns: planning, in-air flight operations
3. To provide a common system for post-event exploratory analysis
4. To provide the data (satellite and model) that are included in the TCIS

Table 1. Summary of the spatial and temporal coverage for all components of TCIS. The domain of the NAHW has expanded over the years. Given are the dimensions of the current domain.

Portals	Temporal Coverage	Domain
NAHW	2012-present	Latitude: 10S – 60N; Longitude: 175W – 0W
CAMP2Ex	2018-present	Latitude: 15S – 35N; Longitude: 40E – 180E
CPEX	05/15/2017 – 07/15/2017	Latitude: 10N – 40N; Longitude: 100W – 45W
CPEX-AW	June 2020 - present	Latitude: 5S – 45N; Longitude: 100W – 40E
TC Data Archive	1999-2010	Global

Table 2. Types and sources for the satellite data routinely included in TCIS

The color-coding reflects the following:

**** Atmospheric composition **** Thermodynamics **** Surface **** Convective Activity

	SENSORS	DATA PRODUCTS	DATA SOURCES
	MODIS	Aerosol Optical Thickness	LAADS DAAC
	AIRS	Temperature and Water Vapor – vertical profiles;	GES-DISC
	MHS, ATMS (NOAA, MetOp, NPP)	Total Precipitable Water	NOAA-NESDIS, CLASS
	MUR-SST	Sea Surface Temperature	JPL PO.DAAC
	QuikSCAT; RapidScat	Surface vector winds over the oceans	JPL PO.DAAC
	ASCAT-A; ASCAT-B	Surface vector winds over the oceans	KNMI/JPL PO.DAAC
	ScatSat	Surface vector winds over the ocean	JPL product from ISRO's observations
	SMAP	Surface wind speed over the ocean	JPL product
	CYGSS	Surface wind speed over the ocean	JPL PO.DAAC
	GOES-E and GOES-W; Himawari-AHI	Geostationary IR (~ 11 um and ~6.7 um water vapor); VIS	NOAA/CLASS; NRL; CIMSS-SSEC;
	TMI, GMI, AMSR2, SSMI, SSMIS	Brightness temperatures 10-89 GHz;	GPM - NASA GSFC PPS
	TMI, GMI, AMSR2, SSMIS	Rain Indicator – 2D maps of relative rain intensity	JPL Derived Product
	GPM-IMERG	Integrated Multi-instrument 1-hour rain totals	GPM - NASA GSFC PPS
	"Best Track"	Hurricane location, estimated maximum wind speed and minimum MSLP, updated every 6 hours	NCAR/RAL**
	TC DATA ARCHIVE ONLY		
	OMI	Ozone – total column;	GES-DISC
	MLS	Ozone - vertical profiles:	GES-DISC
	MLS	Temperature, Water Vapor - vertical profiles	GES-DISC
	MLS	Ice Content – vertical profiles	GES-DISC
	TRMM-PR	Precipitation; Radar Reflectivity – 3D structure	GPM - NASA GSFC PPS
	CloudSat	Clouds and precipitation; Radar Backscatter; vertical profiles	Cloudsat Data Processing Center/CSU

Table 3. Types and sources of model fields available in TCIS. For each model, listed are the specific portals which provide the data. Period of availability is given in parenthesis.

	MODELS	DATA PRODUCTS	DATA SOURCES
	GFS - NAHW - CPEX - CAMP2Ex	- Temperature, Relative Humidity, Horizontal wind - at standard pressure levels; - 2D fields: o 10m winds/2m temperature/SST/MSLP o Integrated Precipitable Water; shear (deep and low-level)	NOMADS/NCEP/NOAA MRG
	ECMWF - NAHW (2012-2016)	- Temperature, Relative Humidity, Horizontal wind - at standard pressure levels; - 2D fields: o Integrated Precipitable Water o Shear (deep and low-level)	MRG
	UKMET - NAHW (2012-2014)	- Temperature, Relative Humidity, Horizontal wind - at standard pressure levels; - 2D fields: o Integrated Precipitable Water o Shear (deep and low-level)	MRG
	ECMWF - CAMP2Ex (2019-present)	- Temperature, Relative Humidity, Horizontal wind, Vertical velocity - at standard pressure levels; - 2D fields: o 10m winds/2m temperature/2m dewpoint/SST/MSLP o Integrated Precipitable Water o Total Precipitation	CAMP2Ex Team
	GEOS5 - CAMP2Ex (07/2019-present) - NAHW (10/2019-present)	- Temperature, Relative Humidity, Horizontal Wind, vertical velocity - at standard pressure levels; - 2D fields: o 10m winds/2m temperature/2m humidity; o Integrated Precipitable Water; Integrated Ice Water Path; Integrated Liquid Water o Aerosol Optical Depth/Tickness (AOD) - Total o AOD Coarse Mode o AOD Fine Mode	NCCS/GSFC MDISC
	HWRF (regional model) - NAHW (2013-2015)	- Synthetic microwave brightness temperatures - Rain Index	EMC/NCEP/NOAA

2. Features

Best Track

Forecasted Tracks

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NORTH ATLANTIC HURRICANE WATCH [NAHW]

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Tropical Cyclone Information System > NAHW Portal | Help

The current selected time: 2012-10-30 18:00:00

Hurricanes: Sandy (10/23-10/30, Cat 2)

October 2012

S	M	T	W	T	F	S
01	02	03	04	05	06	
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Ending at hour: 18:00:00

STORM TRACK

- BEST TRACK
- POUCH TRACK (MRG)
 - P40L
 - P43L

SATELLITE DATA

- AIRS
- CAPE
- LI
- RH Press: 200
- AOT (MODIS)
 - AOT-FINE-TERRA
 - AOT-TERRA
- GOES-East
 - IR
 - IR 2 Day Animation
 - IRCCOLOR
 - VAPOR
 - VIS
- Microwave Rain Signature
- SST
- TPW
- TRMM
- WIND
- TPW

MODEL & SIMULATION DATA

Name: Sandy-18L
Time: 2012-10-25 06:00:00
Location: 20.1N, -75.9W
Wind Speed: 95 knots
Central Pressure: 954 mb

- Early Forecast
- Late Forecast
- Ensemble Forecast

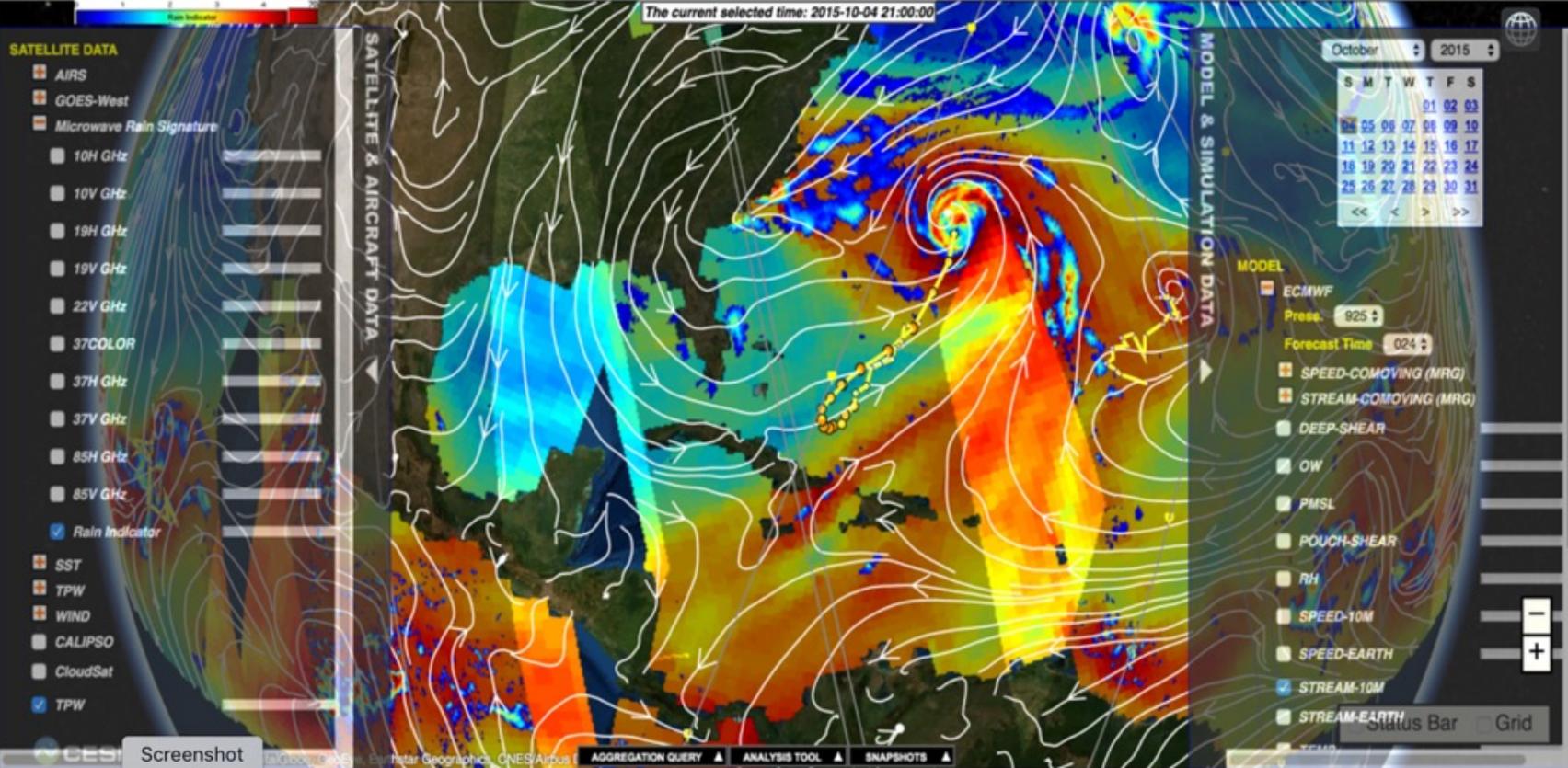
Site Manager: Svetla M Hristova-Veleva PRIVACY Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



NORTH ATLANTIC HURRICANE WATCH [NAHW]

Tropical Cyclone Information System > NAHW Portal | Help

The current selected time: 2015-10-04 21:00:00



Screenshot

3. Analysis Tools

Looking at the storm structure

The "Slicer" – analysis of the Storm

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HURRICANE AND

2014-08-19 15:00:00

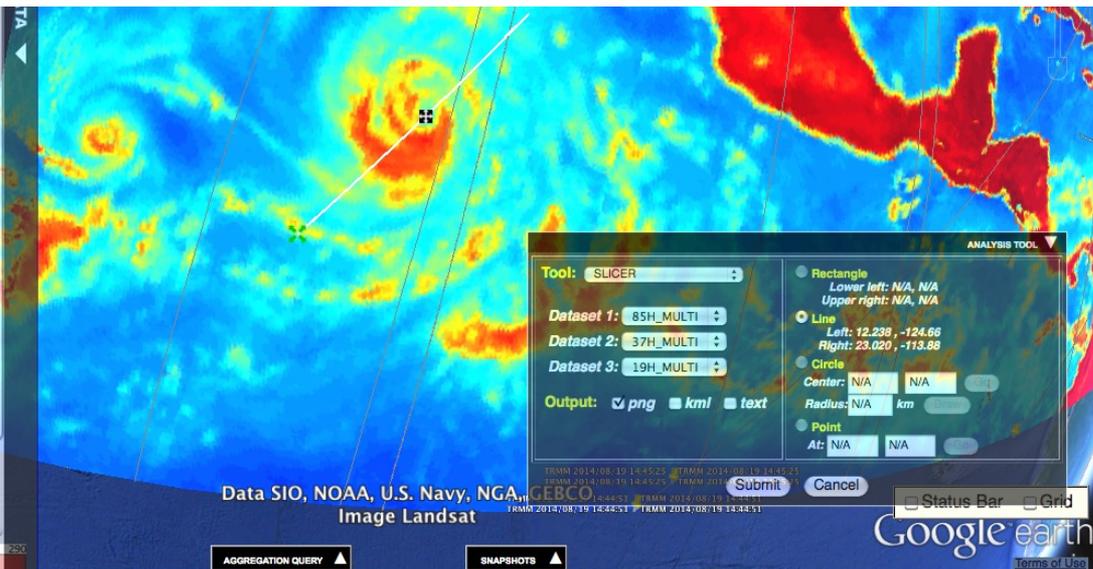
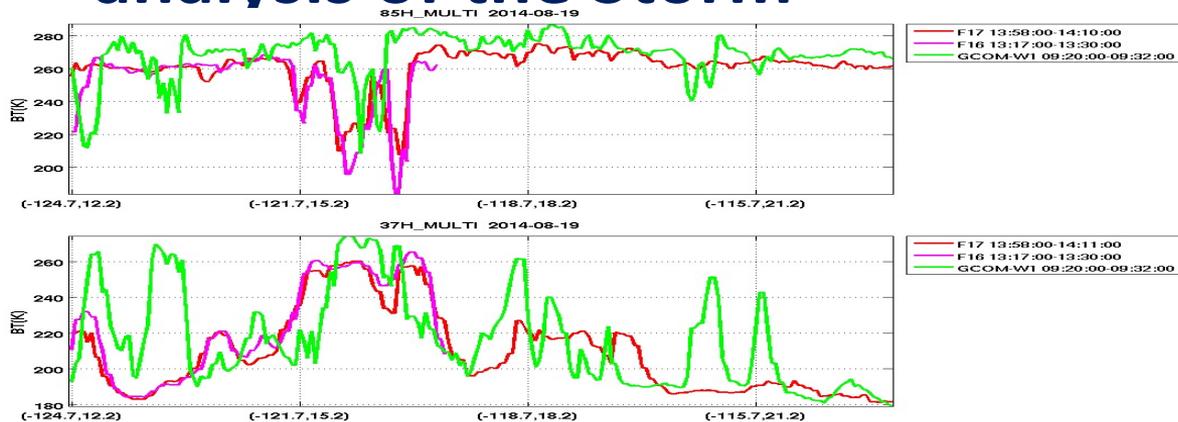
Ending at hour: 15:00

STORM TRACK

- BEST TRACK
- POUCH TRACK

SATELLITE DATA

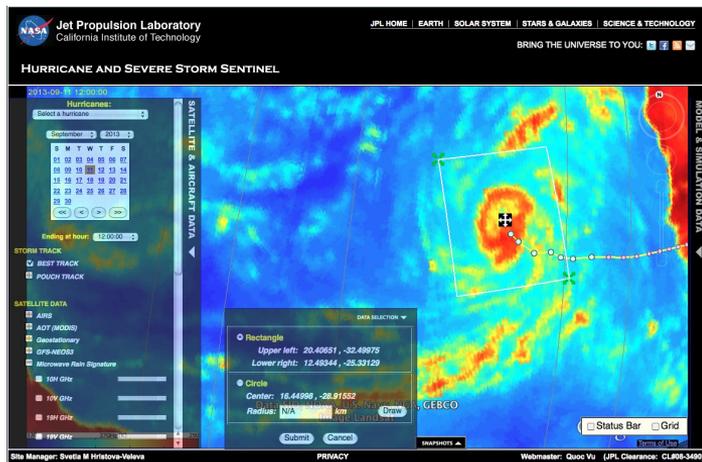
- AIRS
- AOT (MODIS)
- Geostationary
- Microwave Rain Signature
 - 10H GHz
 - 10V GHz
 - 19H GHz
 - 19V GHz
 - 37COLOR
 - 37H GHz
 - 37V GHz
 - 85H GHz
 - 85V GHz
- Rain Indicator
- MLS
- TPW
- 6 HR Composite
- Two Day Animation
- TRMM
- WIND
- CloudSat



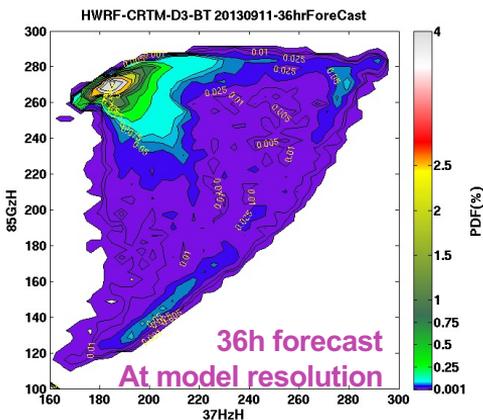
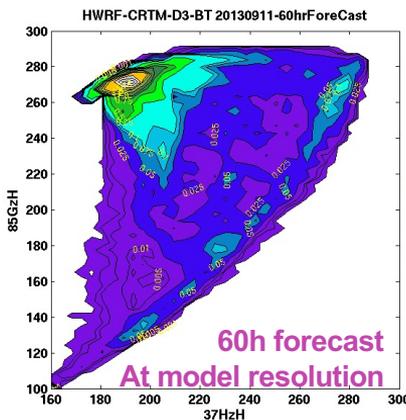
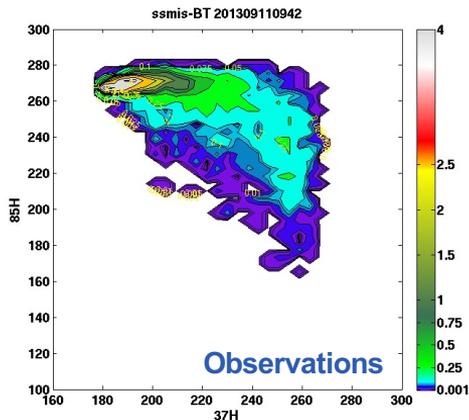
Data SIO, NOAA, U.S. Navy, NGA, Image Landsat

Statistical Tool: *Joint Distribution of Brightness Temperatures*

Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



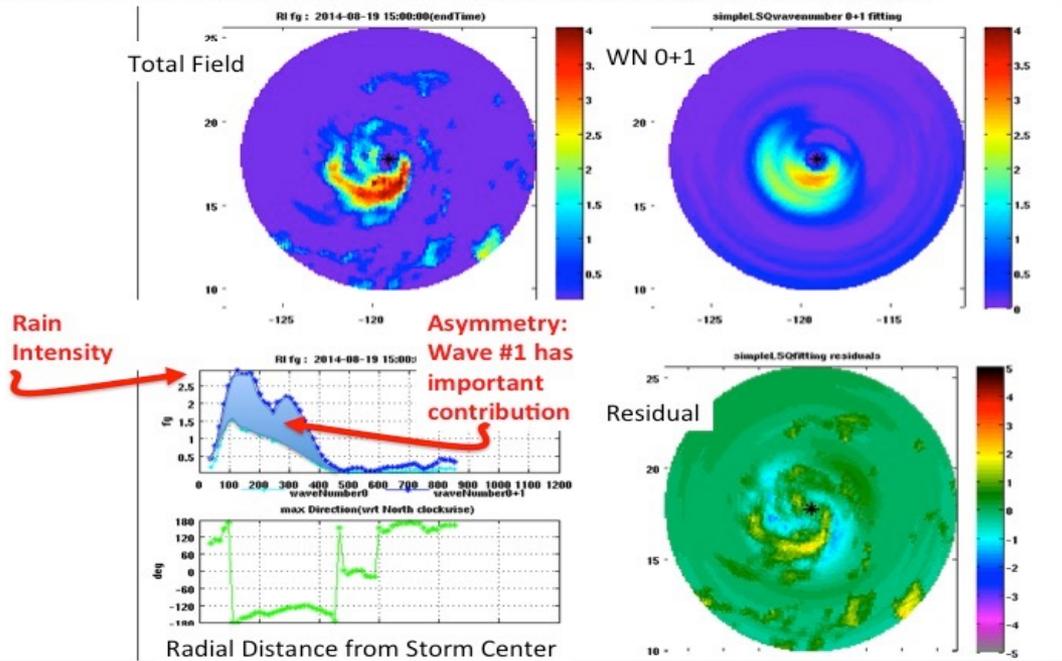
- The statistical relationship between the 37 GHz TBs and the 85 GHz TB presents information on the vertical structure of the storm
- The vertical branch indicates too much scattering of radiation by the frozen precipitation
- Question: Is the ice too much or is its forward modeling inaccurate?
- Need to consider the resolution!



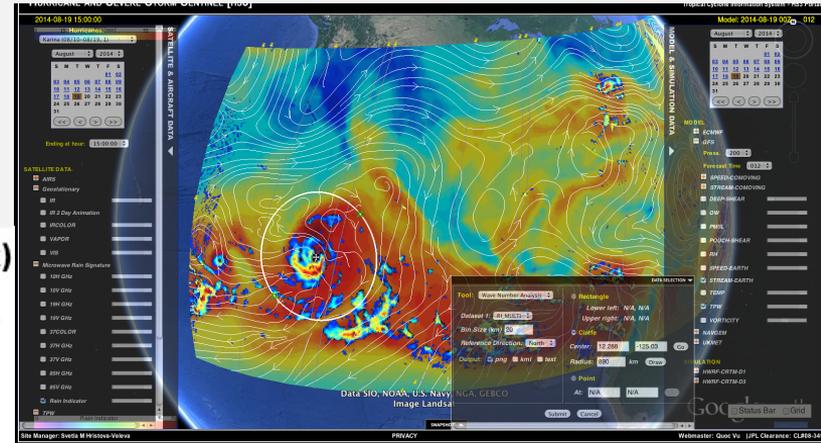
TOOLS:

Wave Number Analysis (WNA) (online)

Wave Number Analysis of the Rain Field (as depicted by the Rain Index)
passive microwave observations: **FEATURES** of the Rain Field



The JPL Tropical Cyclone Information System and The North Atlantic Hurricane Watch



WNA can be used to evaluate
three important quantities:

- the degree of storm symmetry
- the precipitation intensity
- the radial distribution of precipitation/wind

Questions regarding hurricane evolution:

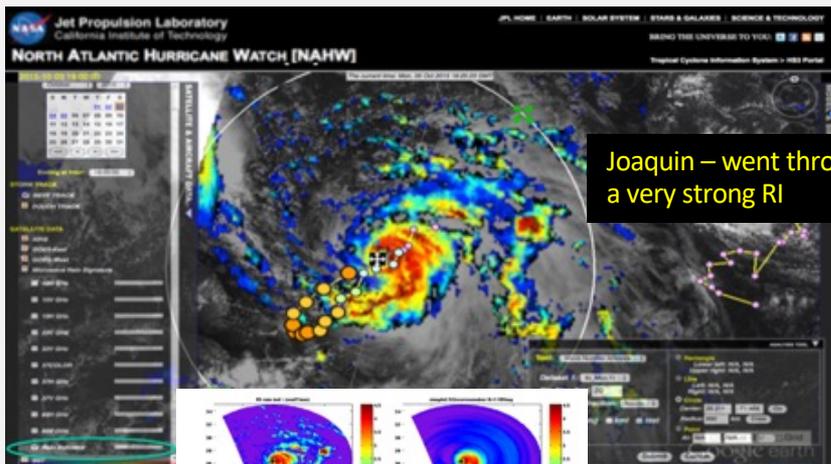
What is the role of the azimuthally symmetric, weak convection?

What is the role of the isolated, intense convection?

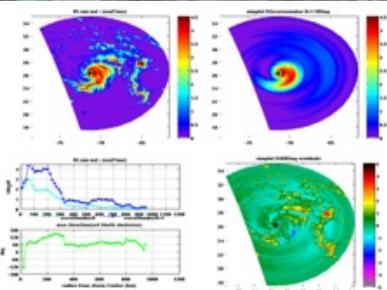
What is the importance of the radial distribution of convection?

Can we use satellite observations to understand these roles? – It seems so ... 😊

The JPL Tropical Cyclone Information System and The North Atlantic Hurricane Watch



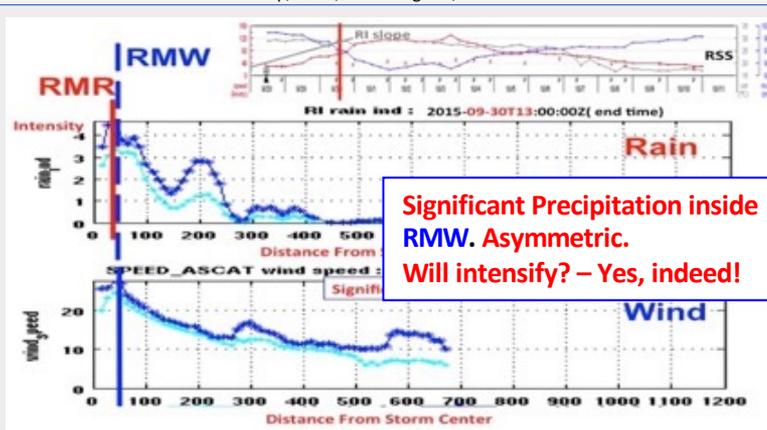
Joaquin – went through a very strong RI



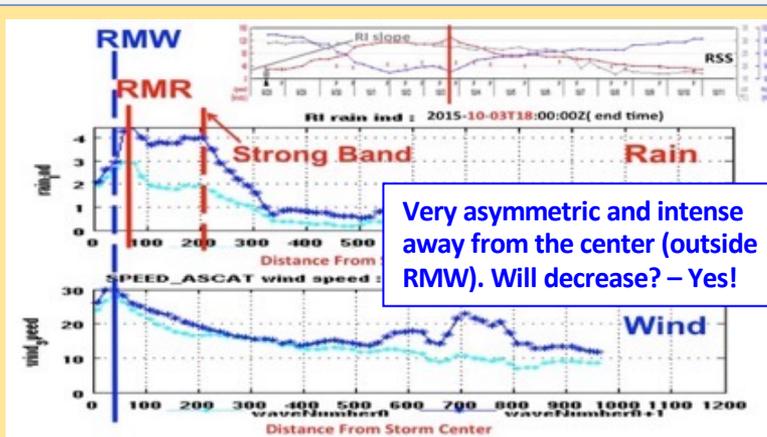
Wave Number Analysis (online)

Possible predictors for the Rapid Intensification and evolution of hurricanes from satellite observations of precipitation and surface winds

Svetla Hristova-Veleva, Z. Haddad, B. Stiles, T.-P. Shen, N. Niamsuwan, F. J. Turk, P. P. Li, B. Knosp, Q. Vu, B. Lambrigtsen, W. Poulsen



Significant Precipitation inside RMW. Asymmetric. Will intensify? – Yes, indeed!



Very asymmetric and intense away from the center (outside RMW). Will decrease? – Yes!

3. Analysis Tools

Analyzing the moisture in the environment

Line for the vertical cross-section shown three slides later

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NORTH ATLANTIC HURRICANE WATCH [NAHW]

The current selected time: 2015-09-30 20:00:00

GFS; 2015-09-30; 24h forecast; Relative Humidity at 500 mb

Hurricanes: Select a hurricane

September 2015

S	M	T	W	T	F	S
		01	02	03	04	05
06	07	08	09	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Ending at hour: 20:00:00

STORM TRACK

- BEST TRACK
- POUCH TRACK

SATELLITE DATA

- AIRS
- CAPE
- LI
- RH Press: 500
- TEMP Press: 200
- AOT (MODIS)
- GOES-East
- IR

MODEL & SIMULATION DATA

MODEL

- ECMWF
- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- GFS
- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- PMSL
- STREAM-EARTH
- TEMP
- TPW

STATUS BAR

Status Bar Grid

ANALYSIS TOOL

Tool: SLICER

- IR/COLOR
- Line

Dataset 1:	RH_GFS	Left: -75.94	4.64	Go
Dataset 2:	N/A	Right: -77.84	42.52	Go
Dataset 3:	N/A	Center: -76.94	23.58	Go

Output: png Rain Signature

MLS

Submit Cancel

AGGREGATION QUERY Mapping, Aerogrid, IGN SNAPSHOTS | the GIS User Community

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Line for the vertical cross-section shown two slides later

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NORTH ATLANTIC HURRICANE WATCH [NAHW]

**ECMWF; 2015-09-30; 24h forecast;
Relative Humidity at 500 mb**

The current selected time: 2015-09-30 20:00:00

Hurricanes: Select a hurricane

September 2015

S	M	T	W	T	F	S
		01	02	03	04	05
06	07	08	09	10	11	12
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Ending at hour: 20:00:00

STORM TRACK

- BEST TRACK
- POUCH TRACK

SATELLITE DATA

- AIRS
- CAPE
- LI
- RH Press: 500
- TEMP Press: 200
- AOT (MODIS)
- GOES-East
- IR

SATELLITE & AIRCRAFT DATA

MODEL & SIMULATION DATA

MODEL

- ECMWF
- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- GFS
- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- PMSL
- RH
- STREAM-EARTH
- TEMP
- TPW

Status Bar Grid

ANALYSIS TOOL

Tool: SLICER

- IRCOLOR
- Line

Dataset 1: RH_ECMWF

Dataset 2: N/A

Dataset 3: N/A

Output: png Rain Signature

Submit Cancel

AGGREGATION QUERY Mapping, Aerogrid, IGN SNAPSHOTS the GIS User Community

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Line for the vertical cross-section shown on the next slide

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JPL

NAHW NORTH ATLANTIC HURRICANE WATCH [NAHW]

2015-09-30; 20Z;
Relative Humidity at 500 mb

The current selected time: 2015-09-30 20:00:00

Hurricanes: Select a hurricane

September 2015

S	M	T	W	T	F	S
01	02	03	04	05		
06	07	08	09	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
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Ending at hour: 20:00:00

STORM TRACK

- BEST TRACK
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SATELLITE DATA

- AIRS
- CAPE
- LI
- RH Press: 500
- TEMP Press: 200
- AOT (MODIS)
- GOES-East
- IR

SATELLITE & AIRCRAFT DATA

MODEL & SIMULATION DATA

MODEL

- ECMWF
- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY

GFS

- Press: 500
- Forecast Time: 024
- STREAM-COMOVING
- PMSL
- RH
- STREAM-EARTH
- TEMP
- TPW

Simulation

- HWRF-CRTM-D1
- HWRF-CRTM-D3

ANALYSIS TOOL

Tool: SLICER

- IRCOLOR
- Line

Dataset 1: RH_AIRS

Dataset 2: N/A

Dataset 3: N/A

Output: png Rain Signature

Submit Cancel

Left: -75.9, 4.64

Right: -77.8, 42.52

Center: -76.9, 23.58

Site Manager: Svetla M Hristova-Veleva

PRIVACY

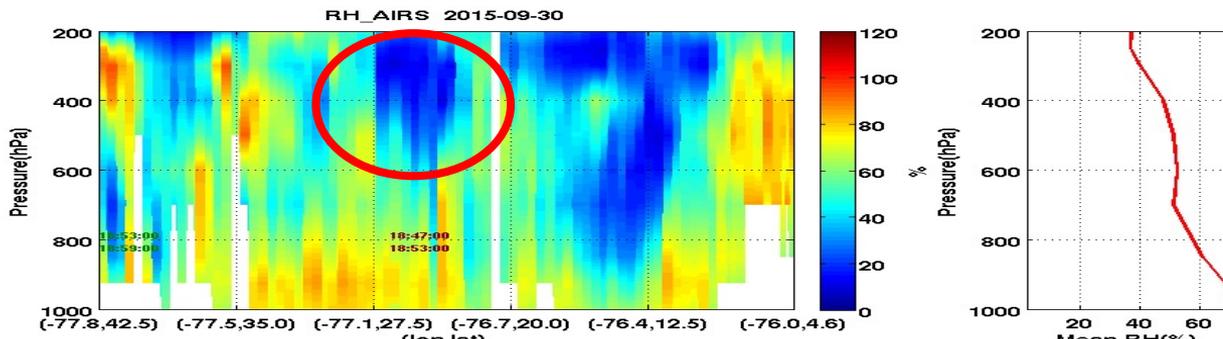
Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

North

Cross-section Along 77W

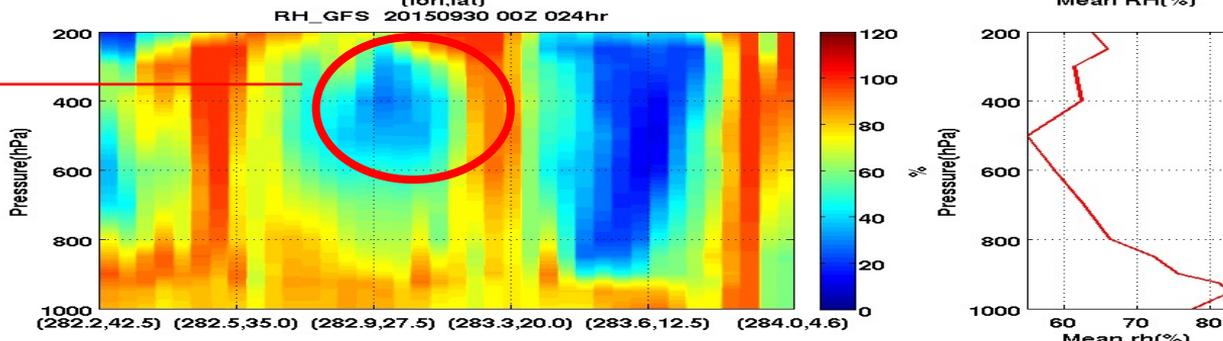
South

AIRS



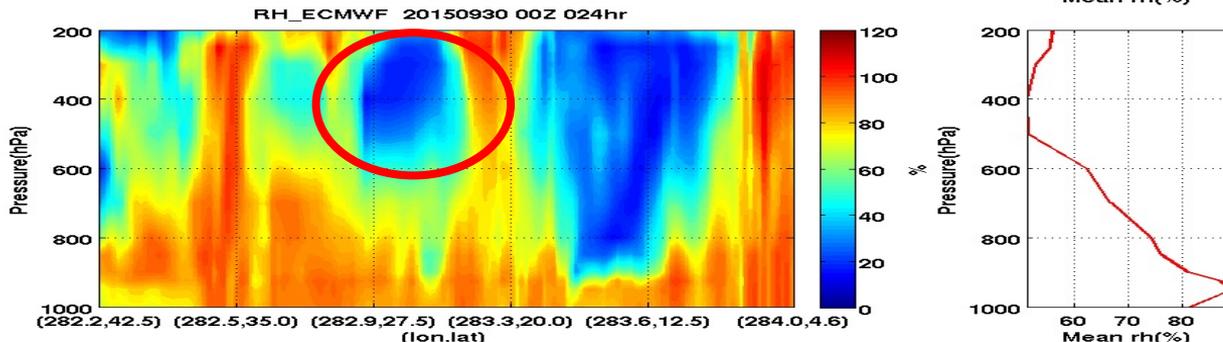
Is GFS too moist at upper levels ahead of the storm??

GFS



Both models seem to have deep layers of moisture that are not seen in the AIRS observations.

ECMWF



4. TC Data Archive

JPL TCIS – The Tropical Cyclone Data Archive

<http://tropicalcyclone.jpl.nasa.gov>

- Satellite depictions of hurricanes over the globe
- 12-year record (1999-2010)
- Offers both data and imagery, making it a unique source to support hurricane research.

Earl, 2010

Download all data from this Instrument (TMI)

The screenshot displays the JPL Tropical Cyclone Information System interface. On the left, a navigation tree lists various instruments and categories, with 'TMI' (Tropical Microwave Imager) selected. The main content area features a 'Timeline' graph showing wind speed and air pressure over time. Below the graph is a 'Storm-Scale data' table. A satellite imagery map shows the cyclone's path over the Pacific Ocean. At the bottom, a calendar for August 2010 is visible, with a 'Download' button circled in red.

Timeline

View and download Storm-scale data

Download Selected large-scale data from this day

JPL Tropical Cyclone Information System

Home Project Feedback Data Portal Analysis Tool

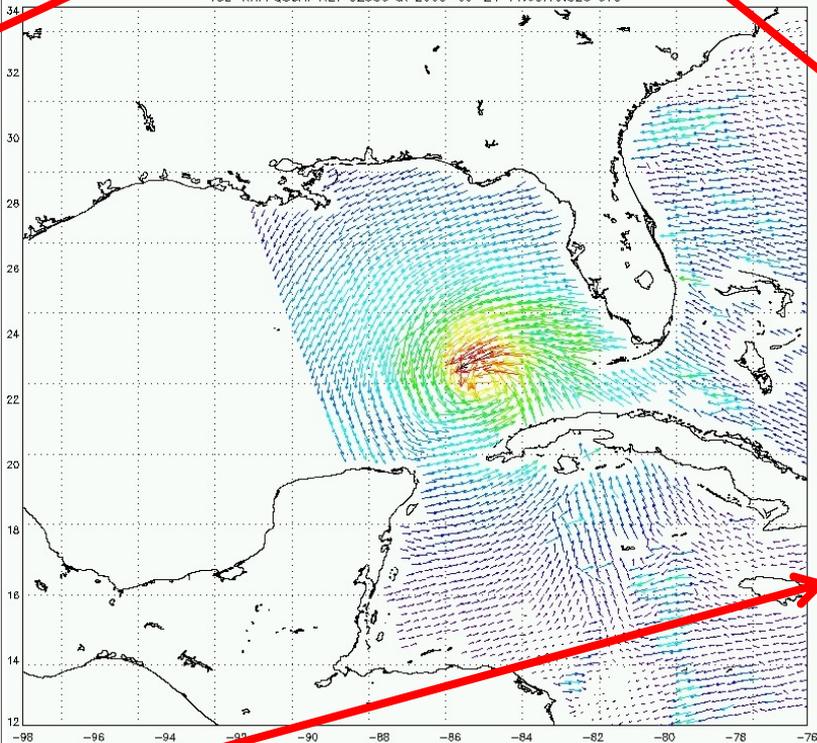
Tropical Cyclone Rita

Su	M	T	W	Th	F	S
			01	02	03	04
05	06	07	08	09	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

September 2005

Download 2005-09-21 11:05:00 SeaWINDS WIND Data

18L-RITA QSCAT REV 32586 at 2005-09-21 11:05:10.825 UTC



Download
NetCDF

At this time

All data on
this day

Download All

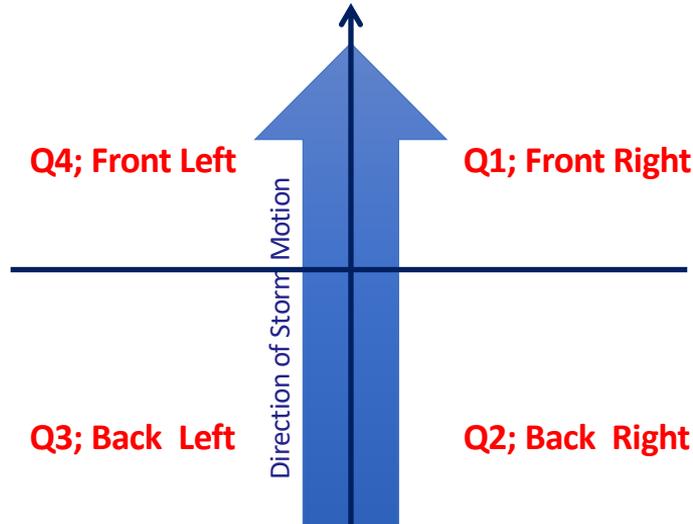


Asymmetry and Evolution

Statistics from observations ; North Atlantic Hurricanes

Parameter as a function of:

- Quadrant with respect to storm motion



Created composites following similar approaches:

Lonfat, M., F.D. Marks, and S.S.Chen, 2004: "Precipitation Distribution in Tropical Cyclones using the Tropical Rainfall Measuring Mission (TRMM) microwave imager : A Global Perspective" MWR 132(7)

Rogers et al., 2012 : "Multiscale analysis of mature tropical cyclone structure from airborne Doppler composites," MWR, 140 (1)

Wu, L, H. Su, R. G. Fovell, B. Wang, J. T. Shen, B. H. Kahn, S. M. Hristova-Veleva, B. H. Lambriksen, E. J. Fetzer, J. H. Jiang, 2012: "Relationship of Environmental Relative Humidity with Tropical Cyclone Intensity and Intensification Rate over North Atlantic", Geophys. Res. Lett., 39, L20809, doi:10.1029/2012GL053546.

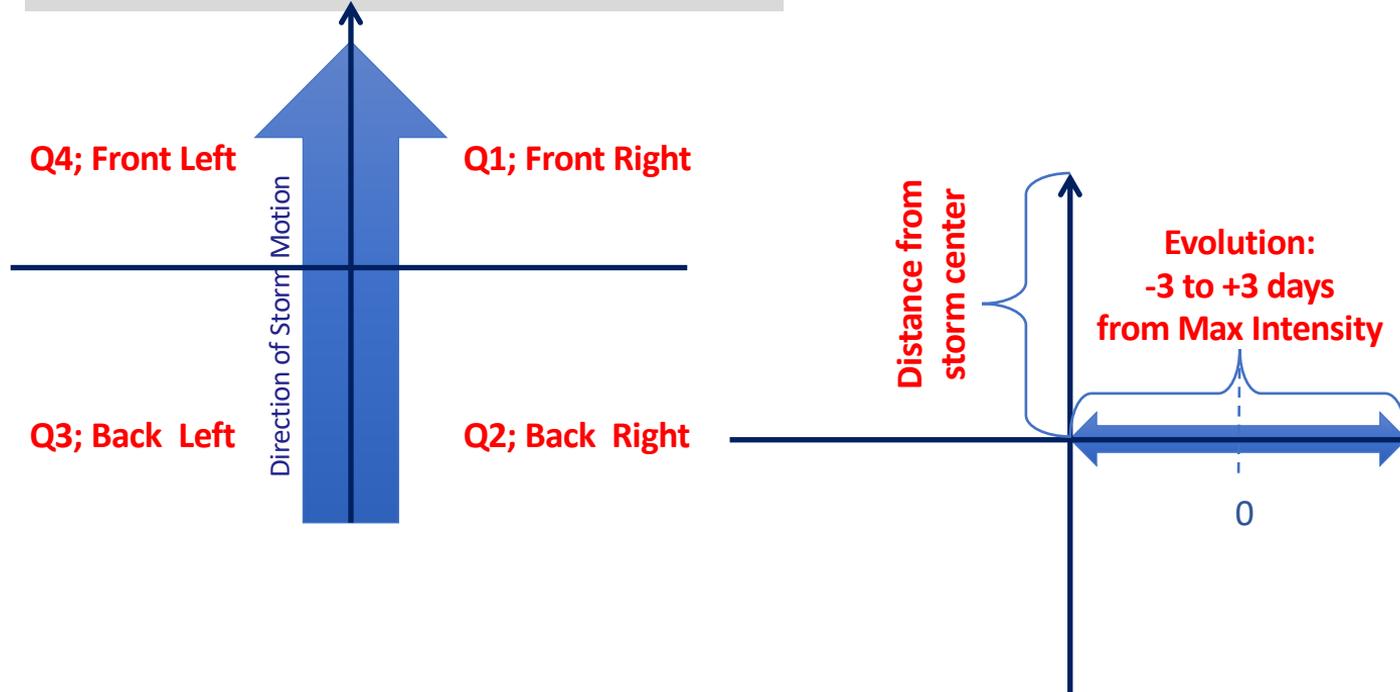
Many others.

Asymmetry and Evolution

Statistics from observations ; North Atlantic Hurricanes

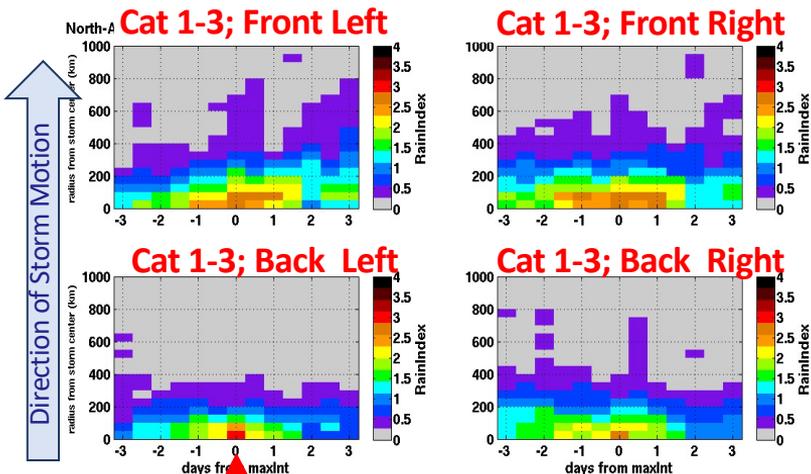
Parameter as a function of:

- Quadrant with respect to storm motion
- distance from storm center (y-axis)
- days from maximum intensity (x-axis)



9-year statistics from AMSR-E observations

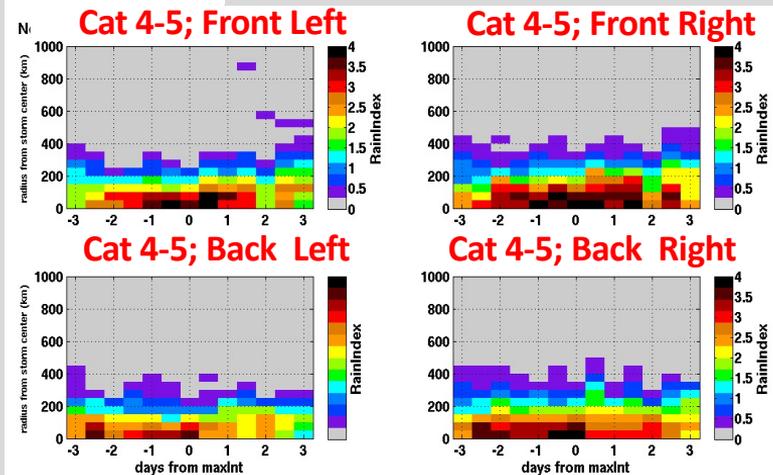
North Atlantic Hurricanes; 2002-2011



Evolution of asymmetry
Azimuthal/Range Distributions
of **Rain Index**

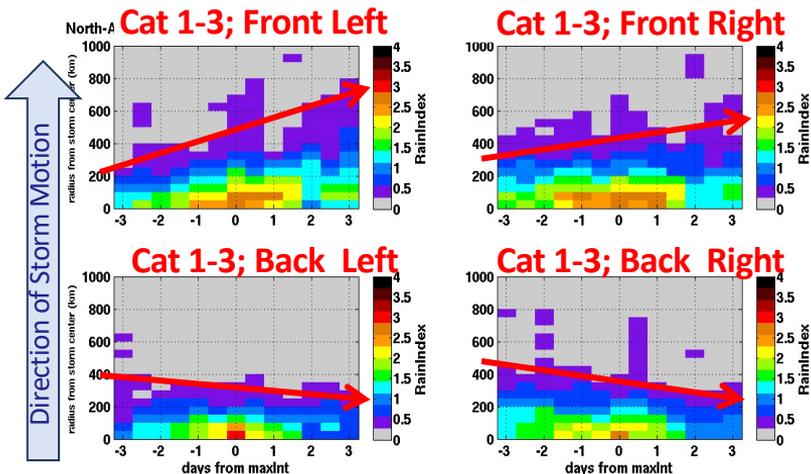
Cat1: 31 cases
Cat2: 9 cases
Cat3: 12 cases
Total Cat1-3 = 52 cases

Cat4: 18 cases
Cat5: 7 cases
Total Cat4-5 = 25 cases



9-year statistics from AMSR-E observations

North Atlantic Hurricanes; 2002-2011



Evolution of asymmetry Azimuthal/Range Distributions of Rain Index

Cat1: 31 cases

Cat2: 9 cases

Cat3: 12 cases

Total Cat1-3 = 52 cases

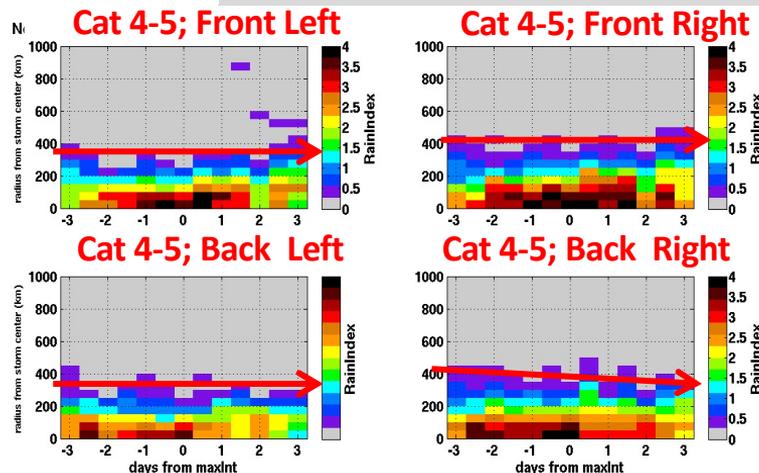
Cat4: 18 cases

Cat5: 7 cases

Total Cat4-5 = 25 cases

Cat 1-3 have rain fields that are **larger, weaker and less symmetric in:**

- Space
 - More intense precipitation is in the **front 2** quadrants
- Time
 - Tendency for radial expansion of precipitation after the peak of the storm. Only in the **front 2** quadrants.
 - Increase in asymmetry



Thank you!